Phase 3 Lake Water Chemistry Monitoring Absaroka Beartooth, Cabinet Mountains, and Selway Bitterroot Wilderness Areas 1994-2001

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Introduction

The US Forest Service Region 1 Air Resource Monitoring Program has emphasized the monitoring of lake chemistry, which provides diagnostic indicators of atmospheric deposition. Region 1 has about 1,750 wilderness lakes, which are a main focal point for Wilderness recreation users but also provide a chemical record of air pollution impacts. This chemical record can indicate changes in a lake's composition, which in sensitive lakes is very diagnostic of atmospheric chemistry. Imbalance of lake chemistry can affect microorganisms, and invertebrates, ultimately affecting the health and productivity of fish. This Report summarizes the overall Region 1 lake sampling program from 1993 through 2001, particularly focusing on the Phase 3 lakes.

R1 ARM Lake Monitoring Program

Since 1989, USFS R1 personnel, primarily Wilderness rangers, and volunteers from Yellowstone Ecosystem Studies have sampled 176 Wilderness lakes in R1. The sampling has consisted of a 3-phase program:

Phase 1: Reconnaissance of lake watershed conditions. Sampling of pH, alkalinity, and conductivity to determine lake buffering potential.

Phase 2: Synoptic chemical characterization of selected lakes (about 50% of Phase 1 lakes) for a wide variety of anions and cations. This phase is designed to provide an overall perspective of the types and variety of chemical processes in the lakes, and distribution of lake types and lake sensitivity relative to watershed factors.

Phase 3: Intensive chemical monitoring of 6 lakes (2 in each of 3 Wilderness areas) to provide a long-term benchmark of trends in acid deposition and other atmospheric related changes I the lake ecosystems.

Six lakes were selected for long term monitoring, two in each of the Cabinet Mountains Wilderness (CMW), Selway Bitterroot Wilderness (SBW), and Absaroka Beartooth Wilderness (ABW) areas. They were chosen because of their sensitivity to acid precipitation and represent other similar lakes in R-1 Wilderness areas.

Sensitivity to acid precipitation is controlled primarily by bedrock at a site and how it physically and chemically weathers. This weathering affects a lake's capacity to neutralize acidity. Most of the Bob Marshall complex, Anaconda Pintler, and Mission Mountain Wilderness areas have predominantly weatherable sedimentary bedrock. This bedrock dissolves relatively easily which contributes chemicals to neutralize acidity (primarily carbonates). Conversely, the Selway Bitterroot, Absaroka Beartooth, and parts of the Cabinet Mountains Wilderness areas have lakes with granite, gneiss, or quartzite bedrock that is resistant to weathering and thus contributes little to neutralize acidity. Further, many of these lakes are in alpine watersheds that have little soil and vegetation and are quite susceptible to acid deposition.

Methods

Criteria for Lake selection**:** Six criteria were used to select the 6 lakes for Phase 3 monitoring:

1) Low ANC and conductivity

2) Lakes with representative chemistry for low ANC lakes in the ABW, CMW, and SBW, and representative depth and morphometry for high elevation lakes in each Wilderness area.

3) Relatively low dissolved sulfate from watershed sources.

4) Reasonable trail access (not possible for the Libby lakes).

5) No obvious man caused effects such as impoundments and fluxuating water levels or historical mining activities in the watershed.

6) Upstream of all other lakes in the drainage, and with non-complex watersheds to facilitate future lake/watershed modeling (MAGIC) model.

Sample Collection**:** Primary and duplicate samples were collected in at the Phase 3 lakes which consisted of Upper and Lower Libby Lakes in the Cabinet Mountains Wilderness (1994-2001), North Kootenai and Shasta Lakes in the Selway Bitterroot Wilderness (1995-2001), and Stepping Stone and Twin Island Lakes in the Absaroka Beartooth Wilderness (1996-2001). In the Libby lakes in 1999 and 2001, samples were be collected in Upper Libby lake from the east side shore, and at the Lower Libby lake outlet. Rafts

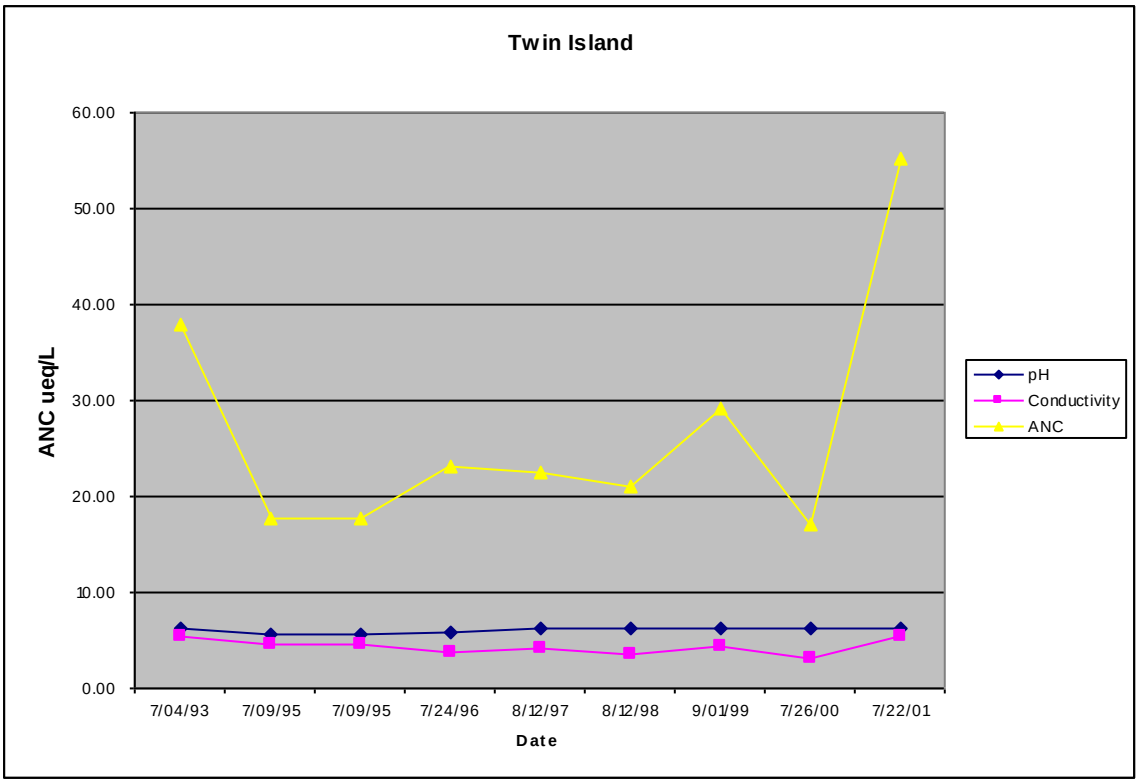
were used for all other Phase 3 lake samples from 1994 – 2001. Samples were also collected from several of the lakes during Phase 2 (1992 and 1993).

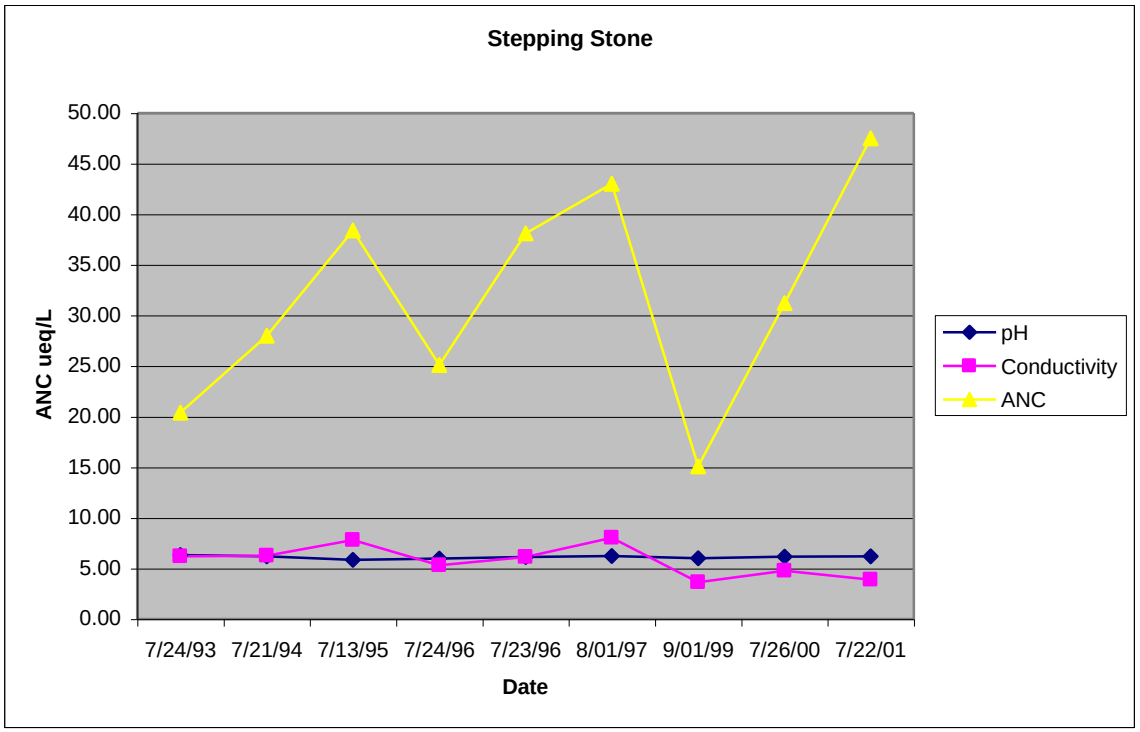
Raft samples were collected at about 0.5 meters (about 1.5 feet in depth) from the raft in the deepest part the lake. Collection bottles include 2 @ 250 ml sample bottles (amber) for a primary sample and a duplicate. One of the 250 ml bottles should be marked as "duplicate. Samples were kept cool in field coolers with frozen gel packs and shipped to the to the USDA Forest Service Rocky Mountain Forest and Range Experiment Station, Biogeochemistry Laboratory as soon as possible.

Biogeochemisry Lab Procedures**:** For pH & alkalinty--Acid Rain Analysis System (ARAS) gran technique; specific conductance--YSI meter; chloride, sulfate, nitrate, ammonia, phosphate, calcium, potassium, sodium, magnesium --liquid ion chromatography; floride--ion specific electrode; aluminum and silica--Lachat flow injection system. Selected magnesium and calcium chromatography values were checked with atomic absorption (Thermo Jarrell Ash 22E). All analyses used QA/QC guidelines and EPA reference standards stablished in the Handbook of Methods for Acid Deposition Studies (EPA 600/4-87/026 and Standard Methods (APHA, 1989). The data was reviewed for conformance with quality assurance standards prior to use. All of the lake data is available on the USFS NRIS-Air database.

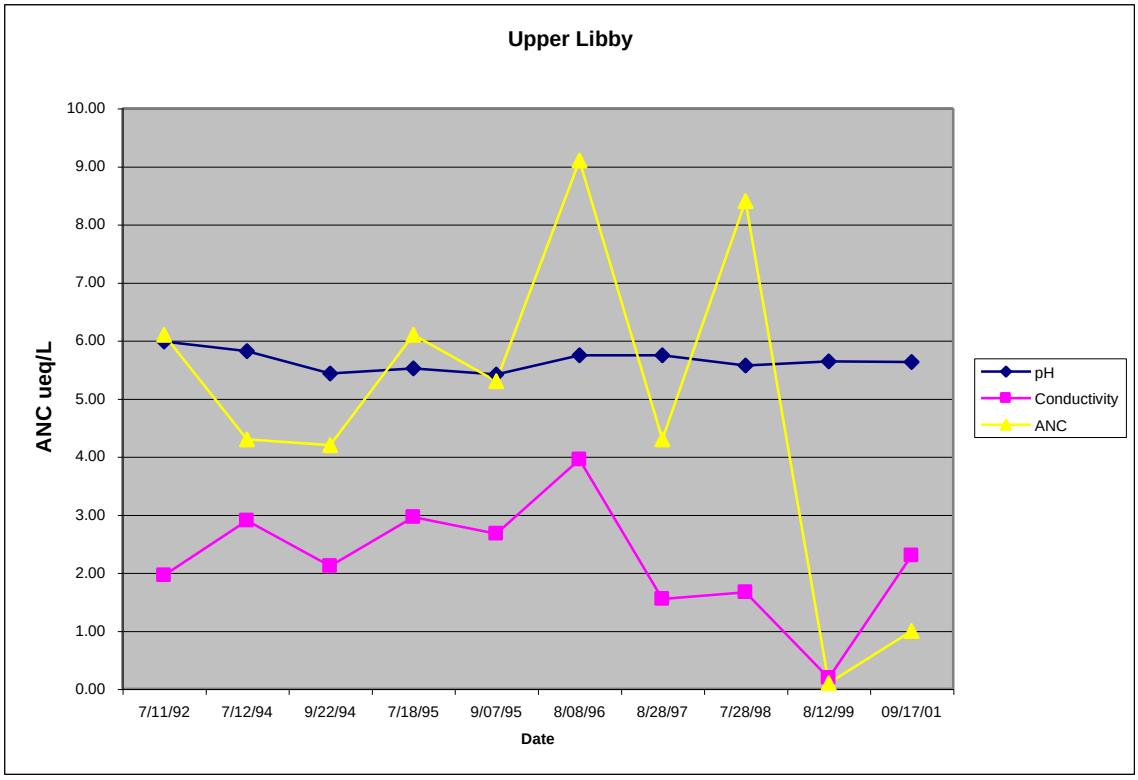
Results and Discussion

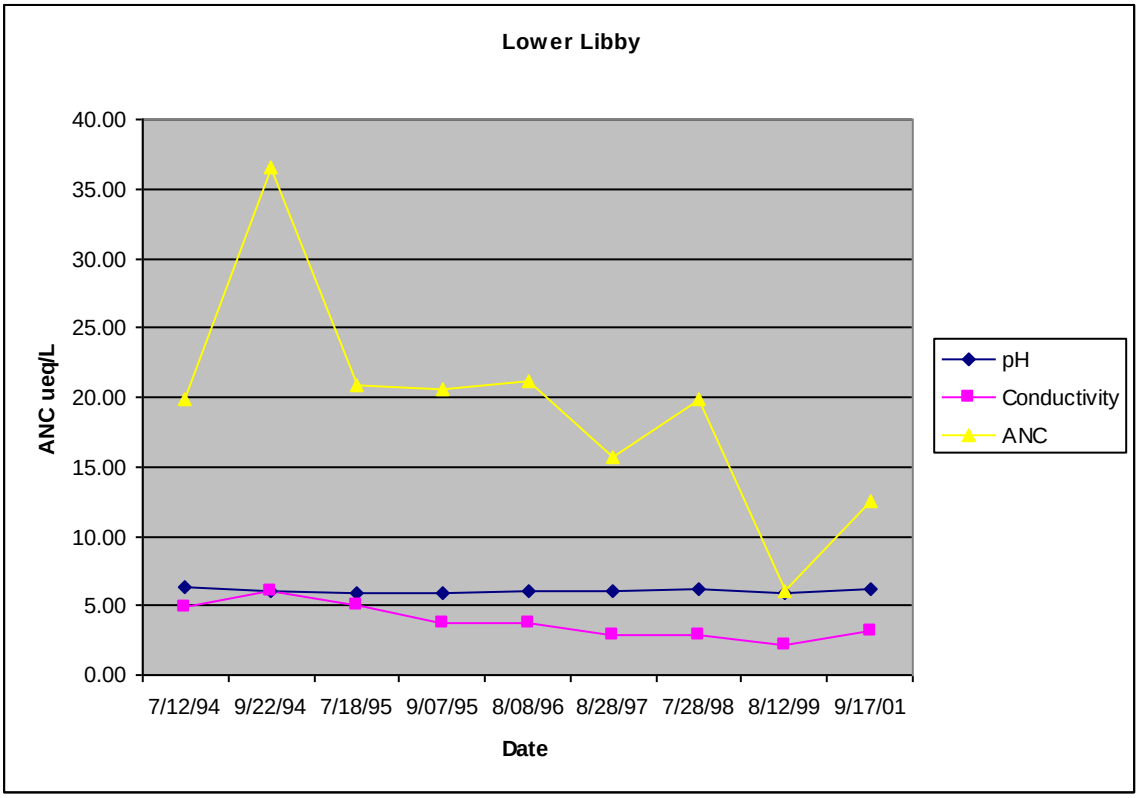
All primary sample data (not duplicates or blank data) for the Phase 3 lakes (including the Phase 2 data from 1992 and 1993) for mg/L and ueq/L is included in the enclosed tables. Previous reports document lake chemistry findings since 1993 (Story, 1993, 1994, 1995, 1996, and 1999). The following graphs of pH, conductivity, and ANC for each of the Phase 3 lakes demonstrate that pH has been stable for each of the lakes but that conductivity and ANC have more variation. Stepping Stone and Twin Island lakes (ABW) have very different patterns with Twin Island lake having relatively high ANC and conductivity when first measured in 1993, decreasing through 1998, then climbing in 1999, decreasing in 2000 and increasing in 2001. Stepping Stone lake, on the other hand, has the opposite pattern with lowest ANC and conductivity in 1993 and 1999. Stepping Stone ANC also increased in 2001 to the highest level measured. Upper Libby and Lower Libby lakes in the CMW have stable pH through the period but declining ANC and conductivity, particularly in 1999 when Upper Libby lake conductivity was measured at only 0.1 ueq/L. Both Upper and Lower Libby lake ANC recovered in 2001 but not to pre-1999 levels. North Kootenai lake in the SBW has stable to slight upward trends in pH, ANC, and conductivity throughout the period of record. Shasta lake has the same pattern as North Kootenai lake but with a decline in 2001.



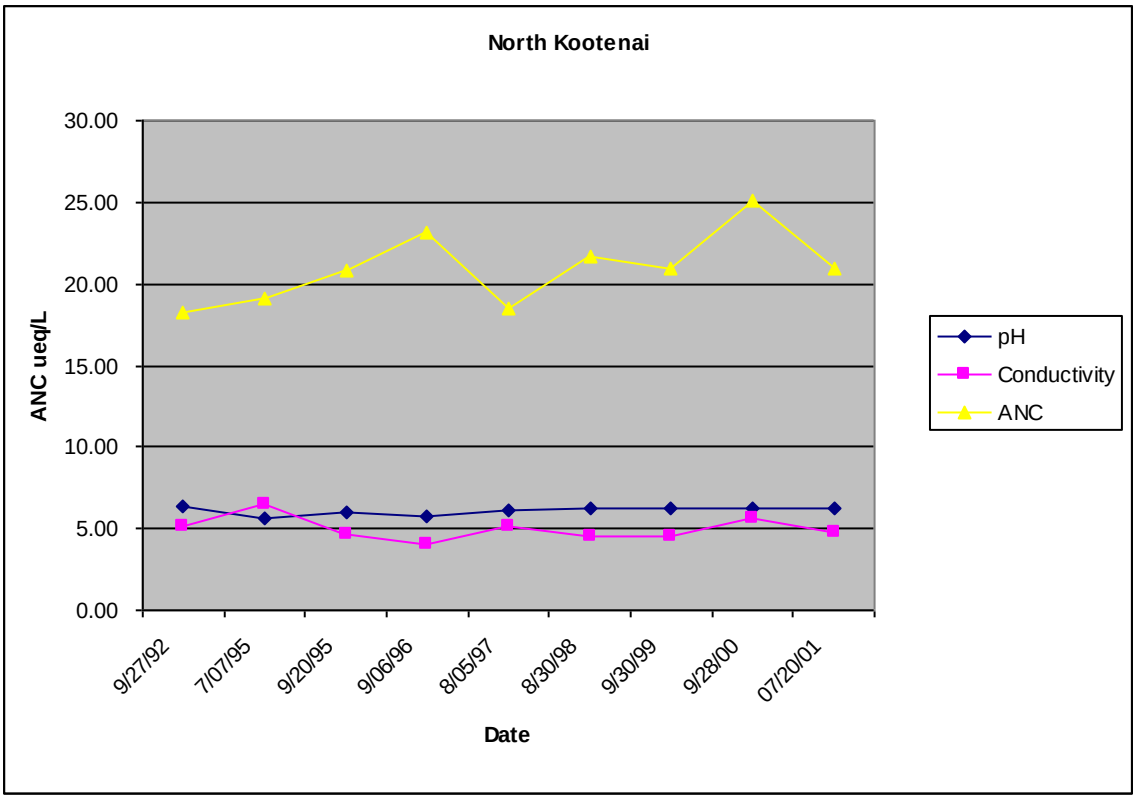


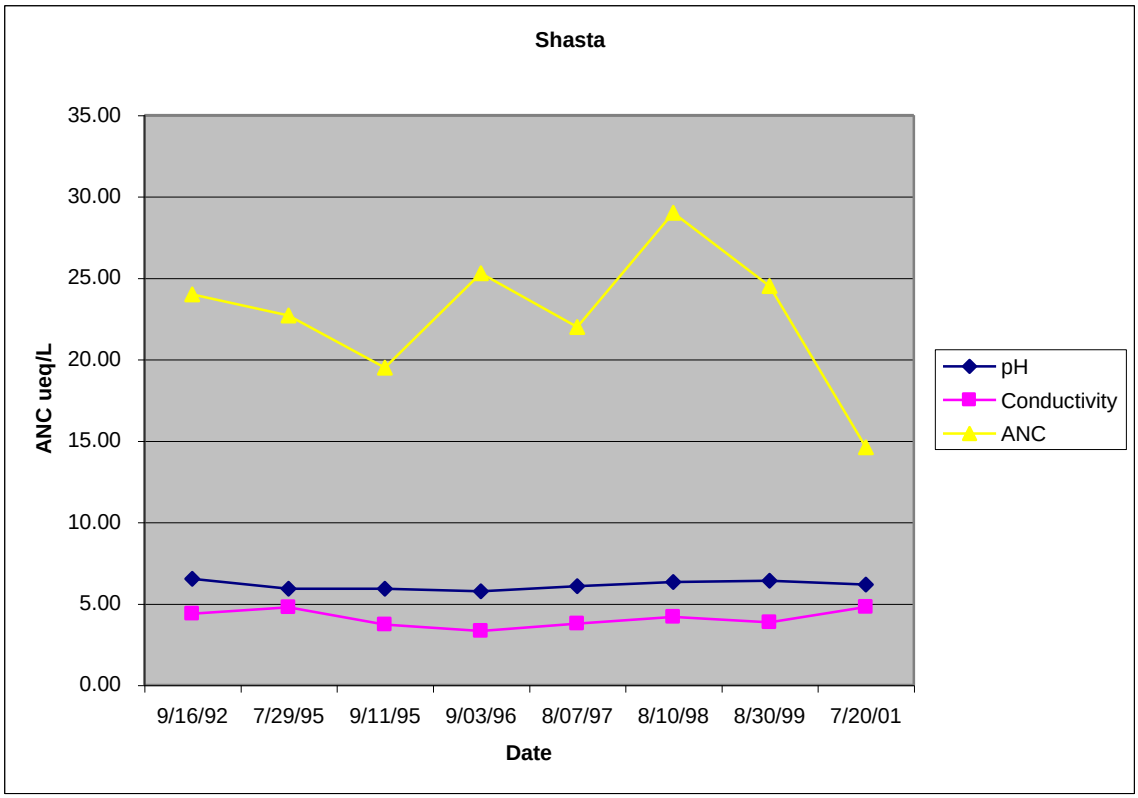
ANC, Conductivity, and pH from Phase 3 Absaroka Beartooth Wilderness Lakes





ANC, Conductivity, and pH from Phase 3 Cabinet Mountains Wilderness Lakes





ANC, Conductivity, and pH from Phase 3 Selway Bitterroot Wilderness Lakes

Variation in lake chemistry is due to a combination of factors including weather patterns, date, time of sampling, and predominant wind patterns during the several days preceding the sampling period. In general, winters with large snow packs, such as in 1996 and 1997, would be expected to "flush" the lake watersheds with more snowmelt dilution. However a flushing effect would be most discernable during snowmelt runoff (primarily late May to late June), which is 1-2 months earlier than most of the Phase 3 sampling. The decline in conductivity and ANC in the Libby Lakes, particularly in 1999 is not readily explainable since no similar trend occurred in the SBW lakes. The Lost Trail Pass NADP site has had a slight decline in pH and an increase in NO3 during 1990 to 1999 (Story, 1999). It is possible that the ANC decline in Libby Lakes may be due to reduced surface inflow to the lakes with a larger percentage of the lake water volume due to direct precipitation. Water entering the lake via precipitation would not interact with the lake watershed vegetation, bedrock, or soils hence would be more dilute. Lake levels in Libby Lakes have notably declined since 1998, particularly Upper Libby Lake.

MAGIC Modeling

A primary purpose of the Phase 3 lake monitoring program is to utilize the sensitive nature of the Phase 3 lakes in defining and protecting these sensitive AQRV's (air quality related values). The MAGIC modeling is included in the AQRV monitoring and sampling plans for the CMW and SBW (Kettner, 1993; Ternes and Ganesan, 1994).

The MAGIC (Model of Acidification of Groundwater in Catchments) model is a state of the art acid deposition watershed/soils/lake chemistry model for non-research watersheds. The model is a lumped parameter model of intermediate complexity which simulates several soil and water chemistry constituents in accounting for atmospheric deposition and watershed interaction of bedrock, soils, and lake dynamics. The model simulates soil solution chemistry and surface water chemistry to predict monthly and annual average concentrations of the major ions in lake water. The model is useful in PSD analysis of lake AQRV's to evaluate if potential upwind emission may pose adverse changes to lake chemistry characteristics.

MAGIC modeling calibrations were completed for Libby Lakes in 1997 (Bernett et. al., 1997: Story, 1997), Shasta and North Kootenai Lakes in 1998 (Eilers et. al., 1998), and for Stepping Stone and Twin Island lakes in 1999. Due to the shallow and quartzite dominated soils in the Libby lakes watersheds, the Libby lakes, particularly upper Libby Lake, are very susceptible to lake acidification. The ABW lakes Stepping Stone and Twin Island are less sensitive due primarily to slightly deeper soils. Shasta and North Kootenai Lakes, although having low ANC's, are relatively less sensitive due to the pockets of deep Palouse soils in their respective lake watersheds.

Monitoring Recommendations

In general, atmospheric/lake chemistry scientists have advised that lake benchmark monitoring, such as the USFS R1 lake monitoring program, occur for at least a 10 year

period to establish baseline and trends. A total of 8 years of Phase 3 lake data is available for the CMW lakes while the SBW and ABW have 6-7 years each. In view of the extensive year to year variation in key atmospheric deposition parameters, and the low ANC and conductivity readings in the Libby lakes (CMW) in 1999 and 2001, it is recommended that the Phase 3 lake monitoring program be continued until at least 2003 for the CMW lakes and through 2004 for the SBW and ABW lakes. In 2002, it would be very useful to sample Libby Lakes 2 times – just after snowmelt runoff (early July) and late summer (September) to test for variation due to lake level.

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